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EFFECT OF BREED AND DIET ON CARCASS PARAMETERS AND MEAT QUALITY OF SPENT HENS

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Abstract

Two spent hen breeds (Mos and Isa Brown) fed with three different diets [commercial feeding (CF); corn, pea, and triticale (CPT); and corn and wheat (CW)] were studied to assess their laying performance, carcass characteristics, and meat quality parameters (breast and drumstick). A total of 48 hens reared in a traditional free-range system were used. Birds were slaughtered at 72 weeks of age after the moulting in an accredited abattoir, and measurements (for each bird) of carcass and meat started at 24 h *post-mortem*. The results demonstrated a breed and diet effect ($P<0.05$) on laying performance, carcass, and meat quality. The Mos breed showed lower laying performance, higher live weight ($P<0.001$), carcass weight ($P<0.001$), dressing percentage ($P<0.001$), and carcass fat ($P<0.001$) than Isa Brown. The breed also affected physicochemical parameters of drumstick and breast ($P<0.05$). Concerning the diet effect, spent hens fed with commercial feeding showed heavier live weight ($P<0.01$) and carcass weight ($P<0.01$). Diet significantly affected most of meat quality parameters, CPT being the formulation that most affected ($P<0.05$) drumstick composition, while in the breast was CF ($P<0.001$). Significant ($P\leq0.005$) effects on breast colour, cooking loss and hardness were observed in animals fed with alternative diets to CF. Regarding nutritional quality, no breed or diet effect ($P<0.05$) was observed in MUFAs, PUFAs and n-6 contents of meat. Overall, both breeds showed a high protein and low-fat content in the breast, showing these hens as an opportunity for the development of meat products as well as an economic purpose for spent hens that reach the end of their productive lives.

Key words: physicochemical composition, nutritional value, fatty acid profile, local breed, free range

In the last years, chicken products (meat and egg) have gained popularity among consumers due to emerging awareness of binomial “health-diet” and demand for low-cost protein (Kim et al., 2020; Mueller et al., 2018). In addition, the global consumption of chicken meat in 2019 was 124,000 tonnes, which means an increase of over 24% in the last 10 years (OECD, 2020). Aiming to meet chicken products demand, in 2018 the global poultry industry had livestock of 69 billion broilers and 7.5 billion laying hens (FAO, 2020). However, concerning chicken meat, the current demand is still higher than the production (Semwogerere et al., 2019). In addition, an important producer of animal-source food such as the European Union had its position as a meat exporter weakened because of high production costs (FAO, 2015).

A possible solution to meet the growing global demand for poultry meat could be to increase options of spent laying hens into the chicken meat supply chain (Semwogerere et al., 2019). Spent hens are laying chickens that have outlived their productive cycle, usually at about 60–72 weeks of age, which need to be replaced after one laying cycle (Wang et al., 2013; Yu et al., 2018). Nonetheless, unlike broilers which are reared for meat production, when old laying hens reach the end of their productive lives (within 1 year) they are considered by-products and are intended for animal feed, ending up in the market at negligible prices (Choe and Kim, 2020; Jin et al., 2007; Safder et al., 2019; Semwogerere et al., 2019). In this way, the use of spent hen meat could be a biologically efficient means for recycling nutrients as well as a profitable approach that meets consumer expectations, following environmental regulations, and maximizes benefits (Freeman et al., 2009; Jin et al., 2007). Indeed, older chickens are considered a delicacy and traditional meal enjoyed in some countries such as the USA (e.g. stewing hens/baking hens), France (e.g. bourride chicken) and Thailand (e.g. tom yum soup) (Semwogerere et al., 2019; USDA, 2019). In addition, spent hens have high amounts of protein and omega-3 fatty acid contents that could provide a new approach for processed food, revaluing their use as a source of protein, lipids, pigments, flavour, and odorous compounds in canned and comminuted products (Jin et al., 2007, 2011; Limpisophon et al., 2019; Polizer et al., 2019) or even as a sustainable animal origin resource (e. g. food-grade lipids) (Safder et al., 2019).

Additionally, the chicken breeds exploited to meat (broilers) and egg (laying hens) by the farms are high-yielding hybrid lines, which could mean a serious threat to biodiversity (Van et al., 2020). Furthermore, industrial lines could show weaknesses in their ability to adapt to climate change, emerging diseases, and variations in consumers demand (meat colour, flavour and texture) as well as welfare conditions found in slow-growing breeds (Rizzi et al., 2007; Van et al., 2020). On the other hand, despite the strong impact of genotype on meat quality, bird feeding has an important effect on poultry meat quality and safety and therefore is closely related to the changes in carcass yield, and sensory characteristics (Franco et al., 2012 a; Mir et al., 2017). In addition, many dual-purpose (eggs and meat) local breeds have demonstrated an adequate capability of meat production in terms of commercial cuts (Rizzi et al., 2007). Moreover, several studies had demonstrated that local breeds (e.g., Mos, Polverara, Black-Boned, Thai Native) are known for their great rusticity, allowing them a better adaptation to different diets and production systems than those showed by hybrids (Zotte et al., 2020; Franco et al., 2016, 2020; Jaturasitha et al., 2008; Pateiro et al., 2018).

Mos breed is an endangered local breed of Galicia (NW Spain) characterized by its dual-purpose (eggs and meat) and great rusticity (Franco, 2012 b). In the last years, conservation programs of the national government and studies with Mos promoted breed recovery and maintenance, hence nowadays this breed has the highest census number of birds in Spain (Franco et al., 2020; MAPA, 2020). Currently, this breed is utilized to produce eggs, roosters, chickens, capons, and young hens in outdoor breeding systems framed in quality poultry production (Pateiro et al., 2018). Several studies have been published evaluating their carcass yield and meat quality (Franco et al., 2013; Franco et al., 2012 a; Franco et al., 2012 b; Franco et al., 2016; Pateiro et al., 2018; Rois et al., 2011), as well as their egg production (Franco et al., 2020), comparing to commercial breeds. However, there is still no information about carcass and meat quality in Mos spent hens.

Hence, considering the status quo in food security, spent hen meat of a local breed could play a crucial role in many countries, and comparative analyses of its physicochemical characteristics and applications need to be performed as a way of occupying an empty market niche (Semwogerere et al., 2019). Therefore, this study aimed to determine the carcass yield, physicochemical characteristics, and fatty acid profile of meat from Mos and Isa Brown spent hens fed with three different diets: commercial feeding, corn/pea/triticale, and corn/wheat.

Material and methods

Experimental design and sample collection

A total of forty-eight laying spent hens (n = 24 of Mos and n = 24 of Isa Brown) at 72 weeks of age were studied. Hens were divided into three groups (each group with 8 hens from each breed) from the 20 weeks of life (with the beginning of laying) according to diets: commercial fodder (CF) with 65% of cereals, corn/pea/triticale (CPT) with corn (40%), triticale (40%) and pea (20%) (n=16), and a mixture of corn (66%) (n=16), and wheat (CW) with corn (66%) and wheat (34%) (n=16). Table 1 shows the chemical composition of the diets used.

Table 1. Chemical composition of the three different diets used in feed systems

Components	Commercial fodder (CF)	Corn, pea, and triticale (CPT)	Corn and wheat (CW)
1	2	3	4
Moisture (%)	9.47	11.05	12.01
Crude protein (%)	14.71	13.16	10.35
Crude fiber (%)	3.00	2.96	2.21
Fat (%)	5.01	2.07	2.89

Table 1 – contd.

1	2	3	4
Ash (%)	7.80	1.78	1.48
Carbohydrates (%)	60.16	68.98	71.07
Energy (Kcal/100 g)	350.55	353.11	356.10
Energy (KJ/100 g)	1482.08	1496.65	1508.75
Minerals (%)			
Ca	1.70	0.05	0.04
P	0.51	0.32	0.27
Na	0.20	0.01	0.02
Fatty acids (%)			
C16:0	29.30	12.11	12.66
C18:0	3.29	1.98	2.22
C18:1n9	29.70	20.48	28.25
C18:2n6	33.10	43.54	52.62
C18:3n3	1.74	3.55	2.17
C20:0	0.32	0.37	0.42
C20:1n9	0.22	0.40	0.45
SFA	34.10	15.16	15.94
MUFA	31.10	21.08	29.22
PUFA	34.90	47.09	54.86
PUFA:SFA	1.02	3.13	3.45

Commercial fodder (CF) with additives: vitamin A (E-672; UI/kg) 7000, vitamin D_3 (E-671; UI/kg) 1750, vitamin E (3a700; UI/kg) 6, Fe (E-1; 42 ppm), Zn (E-6; 35 ppm), Cu (E-4; 4 ppm), Mn (E-5; 42 ppm), Co (E-3; 0.04 ppm), Se (E-8; 0.14 ppm), iodine (E-2; 0.28 ppm) and Fe (E-1; 298 ppm), methionine (3c307; 0.08%), ethoxyquin (E324; 3 ppm), lutein (E-161b; 3 ppm), canthaxanthin (E-161g: 3 ppm) and sepiolite (E-662; 3500 ppm). Corn, pea, and triticale (CPT) with corn (40%), pea (20%), and triticale (40%); Corn and wheat (CW) with corn (66%) and wheat (34%). SFA – ∑ C16:0+ C18:0+ C20:0); MUFA – ∑ (C18:1+ C20:1); PUFA – ∑ (C18:2n6+ C18:3n3+ C18:3n6).

Laying hens were reared in traditional free-range conditions according to Commission Regulation No 543/2008. The “traditional free-range” term can only be used for chickens from a slow-growing strain, with an indoor stocking rate per $m^2 \leq 40$ kg of live weight, and a total usable area of poultry house≤1.600 m^2. In addition, birds must have daytime access to open-air runs covered by vegetation (at least 2 m^2 per chicken), must be fed (fattening stage) with at least 70% of cereals, and slaughtered at ≥81 days of age (OJEU, 2008). Hens of Mos breed were obtained from incubations of existing breeder hens in the Centro de Recursos Zoogeneticos de Galicia (Fontefiz, Ourense, 42º 25’ 47’’N, 7º 50’ 08’’W, 398 m), while Isa Brown (Isa, Netherlands) were purchased from a local dealer (Avilugo, S.L., Vilalba, Lugo). At hatch, the chicks were housed in a pen of 80 m^2 provided with a central hallway, several departments and natural ventilation, with a density of 12 birds/m^2. At the 4th week of life, birds were sexed and moved manually to another pen (departments of the second age) located two meters from the previous one, with a density of 8 birds/m^2. Heaters of 250 W, at the ratio of 1 per 43 chicks, were used as a heat source. Heaters were partially removed at 4 weeks and completely after 6 weeks. From this moment (6 weeks of life), birds were allowed to stay outdoors by opening the self-locking doors of the pen. From the 8th week of life, laying hens were manually transported in cages by vehicle to the definitive pen, located 100 meters from the previous one, with an indoor density of 6 birds/m^2 and outdoor density of 4 m^2/birds according to Regulation No 543/2008 (OJEU, 2008), which establishes implementing rules of Council Regulation (EC) No 1234/2007 regarding poultry meat marketing. An independent pen was arranged for each of the three groups according to the feed system. The three experimental diets were provided *ad libitum*, and water was available all the time. Laying hens did not have additional feeding, having the area of outdoor land during the whole study. Only natural light was used during the study, which was conducted from October 2015 to October 2016. Regarding environmental conditions, the humidity was between 59% (week 44) and 83% (week 8) with an average temperature of 13.9ºC during all the experiment (maximum 38.9ºC at week 48 and minimum of –1.6ºC at week 12). In addition, to avoid infections and diseases in the hens, periodic cleaning and disinfection were carried out in the pens. Daily, the health status of the hens was controlled, making additional openings of gates in the hottest months, and varying the opening hours of laying according to sunlight. Automatic self-locking doors were installed to prevent the entrance of predators.

The birds were slaughtered at 72 weeks of age, after the moulting. Moulting is a natural process in the life of laying hens and consists of the change of old feathers by new ones along with epidermis renovation. In Galicia (NW, Spain) farmers usually finish hens (during 15 days or less) after the moulting aiming to achieve greater carcass weight. Under natural light, this change occurs in autumn (October). This period is an adequate opportunity to produce meat, after the end-of-lay. To be slaughtered the birds were transported to an accredited abattoir with a journey time of 30 min. Hens had a fasting period of 12 h before slaughter. Then, hens were weighed, hung on shackles on a slaughter line, stunned before slaughter in an electrical water bath, killed by manual exsanguination, plucked, and eviscerated. Afterwards, carcasses (identified from 1 to 48 with a leg-tag number) were refrigerated for 12 h at 4°C and then transported to the Centro Tecnológico de la Carne (CTC) of Galicia (Spain). In CTC, 12 h later at 4°C carcasses were weighed and the left side was quartered according to the World's Poultry Science Association recommendations (Jensen, 1984). Carcass weight, dressing percentage, commercial cuts (drumstick, thigh, wing, breast, head, neck, and legs), carcass bone, and carcass fat (perivisceral, perineal, and abdominal) were determined for all hens according to Franco et al. (2013). Drumstick (*Peroneus longus*) and breast (*Pectoralis major*) were used to measure pH (24 h *post-mortem*), chemical composition, and colour parameters, meanwhile, the water holding capacity (quantified by cooking loss) and textural traits were assessed only in breast samples. Measurements of drumstick and breast started at 24 h *post-mortem* and were performed for each bird, a total of 48 samples of drumstick and 48 samples of breast were analysed.

pH, chemical composition and colour parameters

The pH was measured with a digital portable pH-meter (Hanna Instruments, Eibar, Spain) equipped with a penetration probe. Moisture, protein and ash were quantified according to the ISO recommended standards 1442:1997, 937:1978 and 936:1998 (ISO, 1978, 1997, 1998), respectively. The intramuscular fat was determined according to the AOCS Official Procedure Am 5-04 (AOCS, 2005). A portable colourimeter (Konica Minolta CM-600d, Osaka, Japan) with the next settings machine (pulsed xenon arc lamp, angle of 0° viewing angle geometry, standard illuminant D65 and aperture size of 8 mm) was used to evaluate colour parameters (L* – lightness, a* – greenness/redness and b* – blueness/yellowness) in the CIELAB space (CIE, 1976). The colour measurements were obtained after 25 min of bloom time (oxygenation) (Choe and Kim, 2020).

Water holding capacity and texture analysis

For the analysis of water holding capacity (cooking loss), breast cuts were cooked placing them into vacuum-packaged bags in a water bath (80°C) with automatic temperature control (JP Selecta, Precisdg, Barcelona, Spain) until they reached an internal temperature of 70°C, controlled by thermocouples type K (Comark, PK23M, UK) connected to a data logger (Comark Dilligence EVG, N3014, UK). After cooking, breast samples were cooled in a circulatory water bath set at 18°C for 30 min, and the percentage of cooking loss was recorded by measuring the weight difference between the cooked and raw samples.

For texture analysis, a Warner-Bratzler (WB) test was used. To carry out the test, meat pieces of 1 × 1 × 2.5 cm (height × width × length) were cut perpendicular to the muscle fibre direction at a crosshead speed of 3.33 mm/s in a texture analyzer (TA. XT.plus of Stable Micro Systems, Vienna Court, UK) using a WB shear blade with a triangular slot cutting edge (1 mm of thickness). Texture profile analysis (TPA) was measured by compressing pieces of meat of 1 × 1 × 1 cm (height × width × length) to 80% regarding the height of the piece of meat, with a cylindric probe (with a flat surface area of 19.85 cm^2) and the force-time curves were recorded at 1.00 mm/s crosshead speed. Hardness, springiness, cohesiveness, gumminess, and chewiness were obtained.

Fatty acids analysis

For fatty acid analysis, total fat was extracted following the method described by Bligh and Dyer (1959). Twenty milligrams of extracted intramuscular fat were transesterified dissolving in 1 mL of toluene mixed with 2 mL of a sodium methoxide (0.5 N) solution, vortexed for 10 seconds and allowed to stand for 15 min at room temperature. Then, 4 mL of a H_2SO_4 solution (10% of H_2SO_4 in methanol) was added, vortexed for a few seconds and vortexed again before adding 2 mL of saturated sodium bicarbonate solution. For the extraction of fatty acid methyl esters (FAMEs), 1 mL of hexane was added to the oil samples, vortexed for 10 seconds and the organic phase was then transferred to an appropriate GC vial.

Separation and quantification of fatty acids methyl esters (FAMEs) were carried out using a gas chromatograph (GC-Agilent 7890B, Agilent Technologies, Santa

Clara, CA, USA) equipped with a flame ionization detector (FID) and PAL RTC-120 autosampler. One microliter of the sample was injected in split mode (1:50). The injector was maintained at 250°C and 64.2 mL/min of total flow. For the separation of FAMEs, a DB-23 fused silica capillary column (60 m, 0.25 mm i.d., 0.25 µm film thickness; Agilent Technologies) was used. Chromatographic conditions were as follows: initial oven temperature of 50°C (held for 1 min), first ramp at 25°C/min to 175°C, second ramp at 4°C/min to 230°C (held for 5 min) and third ramp at 4°C/min to a final temperature of 240°C (held for 2.75 min). Helium was used as a carrier gas at a constant flow rate of 1.2 mL/min, with the column head pressure set at 22.9 psi. The FID detector was maintained at 280°C, while the operational flows were set as 40 mL/min of H2, 450 mL/min of air and 30 mL/min of makeup flow. The total time for chromatographic analysis was 30 min. Data acquisition and equipment control was carried out using the software MassHunter GC/MS Acquisition B.07.05.2479 (Agilent Technologies, Santa Clara, CA, USA), while the data analysis was carried out with the software MassHunter Quantitative Analysis B.07.01. Individual FAMEs were identified by comparing their retention times with those of authenticated standards [FAME Mix-37 components; docosapentaenoic acid (C22:5n-3; DPA); trans-11 vaccenic acid (11t-C18:1; TVA); cis-vaccenic acid (C18:1n-7; CVA) (Supelco, Madrid, Spain) and conjugated linoleic acid (9c,11t-C18:2; CLA) (Matreya)] and the results were expressed as g/100 g of total fatty acids identified. After obtaining the fatty-acid data, the fractions of saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), omega-3 (n-3) and omega-6 (n-6) fatty acids were determined. The nutritional ratios PUFA/SFA and n-6/n-3 were also calculated.

Statistical analysis

For the statistical analysis of the results of carcass characteristics and meat quality, an analysis of variance (ANOVA) using a GLM procedure of the SPSS package (SPSS 23.0, Chicago, IL, USA) was performed for all variables considered in the study (characteristics of the carcass, physicochemical parameters, and fatty acids as dependent variables). Shapiro–Wilk analysis was used to test the normal distribution and variance homogeneity. The fixed effect of breed and diet was included in the model. The model used was:

$$Y_{ij} = \mu + B_i + F_j + \varepsilon_{ij}$$

where:

Y_{ij} is the observation of dependent variables, μ is the overall mean, B_i is the effect of breed, F_j is the effect of feed, and ε_{ij} is the residual random error associated with the observation. Initially, the interaction B × F was included in the model, but no significant effect was found. The least-square means were separated using Duncan's post hoc test (significance level $P<0.05$).

Results

Feed consumption and laying performance

Table 2 shows laying performance by year (eggs/year) according to breed (Mos and Isa Brown), diet (CF, CPT and CW), and feed consumption (daily and annual).

Table 2. Results for breed and type of diet on annual feed consumption (kg), daily feed consumption (g), and the average number of eggs for 52 weeks

	Mos			Isa Brown		
	Eggs (year)	Daily feed (g)	Annual feed (kg)	Eggs (year)	Daily feed (g)	Annual feed (kg)
CF	185	132	48.26	250	133	48.59
CPT	146	130	47.37	149	133	48.61
CW	154	145	52.81	137	137	49.84

CF – commercial fodder; CPT – corn/pea/triticale; CW – corn/wheat.

As expected, Isa Brown produced many more eggs than Mos when the hens were fed with CF (250 eggs/year *vs*. 185 eggs/year, respectively) since this commercial diet has been developed to maximize the productive capacity of hybrids hens. On the contrary, the results are encouraging concerning egg production with alternative diets (CPT and CW) between both genotypes. Laying performance between Mos *vs*. Isa Brown were similar in the hens fed with CPT diet (146 eggs/year *vs*. 149 eggs/year, respectively) or even higher in Mos if hens were fed with CW diet (154 eggs/year *vs*. 137 eggs/year, respectively).

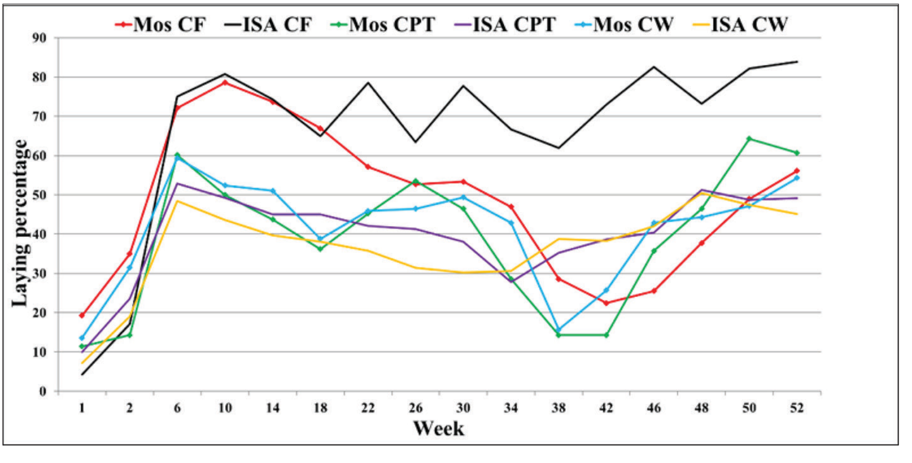

Figure 1. Comparison of laying performance (%) for 52 weeks (Mos *vs*. Isa Brown)

Concerning laying percentage over the 52 weeks (Figure 1), breeds showed similar performance with CPT and CW diets, even with Mos presenting a higher laying percentage at the end-of-lay (final week). Results showed that Isa Brown considerably reduced laying during the 52 weeks if the hens were fed with a non-commercial diet.

Carcass characteristics

The effects of breed and diet on live weight, carcass characteristics, and commercial cuts are shown in Table 3. No interaction (P>0.05) effect was observed between breed and diets.

Table 3. Effects of breed (Mos *vs.* Isa Brown) and diet type on carcass yield and commercial cuts

	Breed		Diet type			P-value		SEM
	Mos	Isa Brown	CF	CPT	CW	breed	diet	
Live weight (kg)	2.88	1.64	2.55 a	1.94 b	2.06 b	<0.001	0.007	0.050
Carcass weight (kg)	2.01	1.02	1.71 a	1.30 b	1.37 b	<0.001	0.006	0.034
Dressing (%)	69.83	63.00	66.28	65.29	66.26	<0.001	0.530	0.759
Commercial cuts (% relative to carcass)								
Drumstick	12.00	12.33	12.26	11.94	12.28	0.041	0.136	0.133
Drumstick skin	1.41	1.04	1.95 a	0.86 b	0.83 b	0.546	<0.001	0.122
Drumstick meat	7.96	8.10	8.14	7.73	8.15	0.124	0.062	0.111
Drumstick bone	2.47	3.60	2.77	3.13	3.33	<0.001	0.156	0.105
Thigh	16.70	16.10	16.51	16.27	16.33	0.064	0.934	0.172
Wing	9.63	11.32	10.09	10.99	10.70	<0.001	0.378	0.150
Breast	19.71	15.43	18.61	16.25	16.97	<0.001	0.131	0.267
Head	3.24	4.64	3.50 c	4.64 a	4.05 b	<0.001	0.020	0.082
Neck	6.12	7.59	6.45	7.33	7.08	<0.001	0.299	0.141
Leg	3.30	4.36	3.69	3.94	4.02	<0.001	0.535	0.126
Carcass bone (%)	30.48	30.82	29.67	32.48	30.35	0.810	0.468	0.688
Carcass fat (%)	3.39	0.85	2.07	2.04	1.86	<0.001	0.155	0.406

a, b, c – means in the same row with different letters differ significantly (P<0.05); SEM – standard error of the mean; CF – commercial fodder; CPT – corn/pea/triticale; CW – corn/wheat.

Breed effect on carcass yield and commercial cuts

Breed showed a significant effect (P<0.05) on live and carcass weight, dressing percentage, all commercial cuts (except for thigh, drumstick skin and meat), and carcass fat. Mos hens had higher values, being almost two times greater than Isa Brown for carcass weight (P<0.001). Regarding noble cuts (drumstick, thigh, wing, and breast) (Table 2), Mos showed significantly lower (P<0.05) percentages of drumstick (12.00% *vs*. 12.33%) and wing (9.63% *vs*. 11.32%) than Isa Brown, but higher values of the breast (19.71% *vs*. 15.43%). Mos showed four times more carcass fat than Isa Brown.

Diet effect on carcass yield and commercial cuts

Diet significantly (P<0.05) influenced the live and carcass weight of the birds studied (Table 3). Live and carcass weight were higher in hens fed with CF, while CPT showed the lowest values. Regarding commercial cuts, only drumstick skin and head showed significant (P<0.05) differences among diets. The head showed higher percentages in hens fed with alternative diets (4.64, 4.05 and 3.50%, for CPT, CW and CF, respectively).

Physicochemical characteristics of meat (drumstick and breast)

The effects of breed and diet on pH, chemical composition, and colour parameters of drumstick and breast are shown in Table 4. No interaction (P>0.05) effect was observed between breed and diets.

Table 4. Effects of breed (Mos *vs.* Isa Brown) and diet type on meat pH, chemical composition, and colour for drumstick (*Peroneus longus*) and breast (*Pectoralis major*)

	Breed		Diet type			P-value		SEM
	Mos	Isa Brown	CF	CPT	CW	Breed	Diet	
Drumstick								
pH	5.89	6.06	5.93	5.96	6.05	0.012	0.243	0.028
composition (%)								
moisture	72.56	74.04	73.49 a	72.47 b	73.31 a	<0.001	0.014	0.224
protein	22.25	22.05	22.06 a	21.37 b	22.67 a	0.897	<0.001	0.121
fat	3.82	2.60	2.55 b	4.50 a	2.77 b	<0.001	<0.001	0.182
ash	1.27	1.31	1.21 b	1.26 b	1.38 a	0.236	<0.001	0.017
Colour								
lightness (L*)	44.15	46.13	45.17 ab	47.90 a	43.70 b	0.043	0.050	0.510
redness (a*)	10.40	9.39	9.59	10.36	9.70	0.008	0.083	0.261
yellowness (b*)	13.13	13.03	13.02 ab	14.44 a	12.28 b	0.133	0.001	0.276
breast								
pH	5.81	5.88	5.82 b	5.78 b	5.92 a	0.099	0.019	0.019
Composition (%)								
moisture	72.47	72.69	72.39	72.50	72.80	0.169	0.054	0.092
protein	25.55	25.73	25.82 a	25.94 a	25.34 b	0.295	0.030	0.098
fat	0.31	0.28	0.12 c	0.48 a	0.31 b	0.259	<0.001	0.027
ash	1.35	1.33	1.33	1.32	1.36	0.522	0.543	0.017
Colour								
lightness (L*)	56.53	57.58	57.06	58.95	56.04	0.123	0.342	0.474
redness (a*)	0.98	1.91	0.23 b	2.06 a	2.16 a	0.266	<0.001	0.272
yellowness (b*)	14.74	14.17	13.79 b	15.86 a	14.03 b	0.004	<0.001	0.210

a, b, c – means in the same row with different letters differ significantly (P<0.05); SEM – standard error of the mean; CF – commercial fodder; CPT – corn/pea/triticale; CW – corn/wheat.

Breed effect on pH, composition, and colour of meat

Looking first at drumstick, pH, moisture content, fat content, and colour characteristics (L* and a*) were significantly affected (P<0.05) by breed. Mos showed lower (P<0.05) pH values than Isa Brown (5.89 *vs*. 6.06, respectively). Concerning drumstick composition, Mos showed significantly (P<0.001) lower moisture (72.56% *vs*. 74.04%) and higher fat content (3.82% *vs*. 2.60%) than Isa Brown. Concerning colour parameters, Mos showed lower (P<0.05) L* and higher (P<0.01) a* values than Isa Brown. In breast, except for b* which showed higher (P<0.01) values in Mos, the breed did not affect (P<0.05) the other physicochemical parameters evaluated (pH, composition, L*, and a*).

Diet effect on pH, composition, and colour of meat

Except for pH and a*, diet significantly (P<0.05) affected all parameters of the drumstick. The diet formulation that most affected (P<0.05) the drumstick composition was CPT (corn, pea, and triticale), with a significant decrease in moisture (P<0.05) and protein (P<0.001) content, and an increase (P<0.001) in fat (up to 76.47%). Despite the differences observed in colour, non-significant (P>0.05) differences were found for a* between commercial fodder and alternative diets. Nonetheless, diets with corn, pea and triticale (CPT) showed higher L* and b* values than diets with corn and wheat (CW).

In breast, diet significantly (P<0.05) affected pH, protein, fat, a* and b*. Within composition, protein was higher (P<0.05) in CF and CPT groups (25.94% and 25.82% *vs*. 25.34%, for CPT, CF and CW, respectively), while fat was lower (P<0.001) in CF (0.12% *vs*. 0.31% and 0.48%, for CF, CW and CPT, respectively).

Textural parameters

The effects of breed and diet composition on cooking loss, shear-force (Warner-Bratzler) and TPA-test results of the breast are shown in Table 5. No significant (P>0.05) effect was observed for interactions between breed and diets.

Table 5. Effects of the breed (Mos *vs*. Isa Brown) and diet type on textural parameters of the breast (*Pectoralis major*)

	Breed		Diet type			P-value		SEM
	Mos	Isa Brown	CF	CPT	CW	breed	diet	
Cooking loss (%)	12.56	12.32	11.21 b	12.56 a	13.29 a	0.492	0.005	0.286
Shear force (N/cm^2)	21.16	21.66	21.76	24.35	19.36	0.558	0.268	0.833
TPA-test								
Hardness (N)	62.46	56.88	69.45 a	60.09 b	51.00 c	0.191	<0.001	1.675
Springiness (mm)	5.11	5.29	5.19 ab	5.52 a	5.04 b	0.532	0.016	0.070
Cohesiveness	5.09	5.59	4.99	5.69	5.29	0.107	0.071	0.080
Gumminess (N)	31.17	30.76	34.18 a	33.30 a	27.00 b	0.842	<0.001	0.823
Chewiness (N×mm)	16.61	16.79	18.41 a	19.25 a	13.84 b	0.915	<0.001	0.530

a, b, c – means in the same row with different letters differ significantly (P<0.05); SEM – standard error of the mean; CF – commercial fodder; CPT – corn/pea/triticale; CW – corn/wheat.

Breed and diet effect on textural parameters of breast

Breed did not have a significant (P>0.05) effect on cooking loss and texture parameters. Diet had a significant (P<0.05) effect on cooking loss, hardness, springiness, gumminess, and chewiness. In the present study, hens fed with CW diet showed the lowest values for hardness (51.00 *vs*. 60.09 and 69.45 N, for CW, CPT and CF, respectively), springiness (5.04 *vs*. 5.19 and 5.52 mm, for CW, CF and CPT, respectively), gumminess (27.00 *vs*. 33.30 and 34.18 N, for CW, CPT and CF, respectively), and chewiness (13.84 *vs*. 18.41 and 19.25 N×mm, for CW, CF and CPT, respectively).

Table 6. Effect of breed (Mos *vs*. Isa Brown) and diet formulation on fatty acid profile (g/100 g of total fatty acids) of drumstick (*Peroneus longus*)

	Breed		Diet type			P-value		SEM
	Mos	Isa Brown	CF	CPT	CW	breed	diet	
C14:0	0.66	0.64	0.72 a	0.68 ab	0.61 b	0.044	0.003	0.015
C14:1n-5	0.17	0.20	0.19	0.17	0.20	0.054	0.132	0.007
C16:0	20.80	20.86	22.88 a	20.87 b	20.15 b	0.079	<0.001	0.232
C16:1n-7	1.95	2.23	2.22	2.13	2.12	0.253	0.999	0.096
C17:0	0.18	0.18	0.17 b	0.20 a	0.18 b	0.708	0.004	0.003
C17:1n-7	0.15	0.13	0.16 a	0.14 ab	0.13 b	<0.001	<0.001	0.004
C18:0	9.73	9.54	8.50 b	9.53 a	10.00 a	0.743	<0.001	0.121
9t-C18:1	0.12	0.13	0.12	0.14	0.12	0.008	0.271	0.004
C18:1n-9	34.27	33.66	32.66	33.94	34.20	0.625	0.248	0.403
C18:1n-7	2.07	2.18	2.17	2.00	2.23	0.133	0.072	0.047
C18:2n-6	23.08	22.36	22.88	23.31	22.06	0.462	0.576	0.603
C18:3n-6	0.14	0.14	0.14	0.15	0.14	0.377	0.509	0.005
C18:3n-3	0.65	0.56	0.72 a	0.72 a	0.46 b	<0.001	<0.001	0.019
C20:1n-9	0.33	0.32	0.31	0.32	0.32	0.553	0.509	0.008
C20:2n-6	0.22	0.21	0.20	0.22	0.20	0.816	0.759	0.008
C20:3n-6	0.21	0.17	0.18	0.18	0.18	<0.001	0.059	0.004
C20:4n-6	3.98	5.01	4.42 ab	3.98 b	5.21 a	0.007	0.010	0.184
C20:5n-3	0.16	0.20	0.17	0.18	0.20	0.054	0.149	0.009
C22:6n-3	0.56	0.72	0.66	0.58	0.73	0.107	0.319	0.039
SFA	31.56	31.40	32.48 a	31.46 ab	31.10 b	0.083	0.024	0.234
MUFA	39.17	38.93	37.89	38.89	39.45	0.412	0.250	0.475
PUFA	29.08	29.47	29.45	29.43	29.27	0.972	0.953	0.619
PUFA/SFA	0.93	0.94	0.31	0.94	0.94	0.606	0.783	0.026
n-3	1.43	1.59	1.61 a	1.67 a	1.45 b	0.724	0.004	0.044
n-6	27.63	27.91	27.82	27.87	27.79	0.916	0.990	0.613
n-6/n-3	20.75	18.66	17.30	19.39	19.95	0.723	0.227	0.789

a, b – means in the same row with different letters differ significantly (P<0.05); SFA=∑ (C14:0 + C15:0 + C16:0 + C17:0 + C18:0+ C20:0 + C21:0 + C22:0 + C23:0 + C24:0); MUFA=∑ (C14:1 + C15:1 + C16:1+ C17:1 + 9t-C18:1 + 11t-C18:1 + C18:1n-9 + C18:1n-7 + C20:1n-9 + C22:1n-9 + C24:1); PUFA=∑ (C18:2n6t +C18:2n-6 + C18:3n-6 + C18:3n-3 + C20:2n-6 + C20:3n-6 + C20:3n-3 + C20:4n-6 + C22:2 + C20:5n-3 + C22:5n-3 + C22:6n-3); CF – commercial fodder; CPT – corn/pea/triticale; CW – corn/wheat.

Table 7. Effect of breed (Mos *vs.* Isa Brown) and diet formulation on fatty acid profile (g/100 g of total fatty acids) of the breast (*Pectoralis major*)

	Breed		Diet type			P-value		SEM
	Mos	Isa Brown	CF	CPT	CW	breed	diet	
C14:0	0.63	0.53	0.68 a	0.61 a	0.51 b	0.006	0.002	0.017
C14:1n-5	0.29	0.26	0.27	0.27	0.29	0.037	0.803	0.007
C16:0	23.67	23.28	23.94	23.41	23.21	0.358	0.370	0.230
C16:1n-7	1.17	1.46	1.22	1.41	1.26	0.018	0.628	0.051
C17:0	0.16	0.16	0.15 b	0.17 a	0.16 b	0.581	0.003	0.002
C17:1n-7	0.15	0.10	0.17 a	0.12 b	0.11 b	<0.001	<0.001	0.005
C18:0	9.79	10.19	8.99 c	9.97 b	10.74 a	0.192	<0.001	0.096
9t-C18:1	0.09	0.10	0.08	0.10	0.09	0.007	0.223	0.003
C18:1n-9	30.03	29.12	29.95	29.69	29.43	0.427	0.935	0.365
C18:1n-7	2.20	2.06	2.12	2.02	2.23	0.144	0.175	0.043
C18:2n-6	18.94	17.46	19.65 a	18.71 ab	17.10 b	0.177	0.033	0.432
C18:3n-6	0.13	0.11	0.13	0.12	0.11	0.275	0.471	0.006
C18:3n-3	0.46	0.41	0.45 b	0.60 a	0.34 c	<0.001	<0.001	0.014
C20:1n-9	0.24	0.25	0.23	0.25	0.25	0.522	0.323	0.008
C20:2n-6	0.23	0.21	0.21	0.23	0.22	0.294	0.305	0.007
C20:3n-6	0.35	0.29	0.33	0.34	0.33	0.008	0.557	0.012
C20:4n-6	8.90	10.86	8.54 b	9.12 b	10.90 a	0.005	0.002	0.286
C20:5n-3	0.43	0.52	0.34 b	0.59 a	0.51 ab	0.607	<0.001	0.016
C22:6n-3	1.60	1.74	1.58	1.70	1.69	0.935	0.686	0.086
SFA	34.44	34.37	33.96	33.36	34.82	0.614	0.224	0.240
MUFA	34.27	33.43	34.24	33.89	33.72	0.565	0.942	0.424
PUFA	31.13	31.71	31.30	31.55	31.29	0.772	0.989	0.540
PUFA/SFA	0.91	0.92	0.92	0.92	0.90	0.712	0.822	0.020
n-3	2.56	2.75	2.42 b	3.00 a	2.61 ab	0.467	0.050	0.092
n-6	28.55	28.95	28.86	28.53	28.66	0.673	0.947	0.531
n-6/n-3	12.13	10.78	12.46	10.28	11.60	0.850	0.342	0.523

a, b – means in the same row with different letters differ significantly (P<0.05); SFA=∑ (C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C21:0 + C22:0 +C23:0 +C24:0); MUFA=∑ (C14:1 +C15:1 + C16:1 + C17:1 + 9t-C18:1 + 11t-C18:1 + C18:1n-9 + C18:1n-7 + C20:1n-9 + C22:1n-9 + C24:1); PUFA=∑ (C18:2n-6t + C18:2n-6 + C18:3n-6 + C18:3n-3 + C20:2n-6 + C20:3n-6 + C20:3n-3 + C20:4n-6 + C22:2 + C20:5n-3 + C22:5n-3 + C22:6n-3); CF – commercial fodder; CPT – corn/pea/triticale; CW – corn/wheat.

Fatty acid profile (drumstick and breast)

The effect of breed (Mos *vs*. Isa Brown) and diet formulation on the fatty acid profile of drumstick and breast are shown in Table 6 and Table 7, respectively. No significant (P>0.05) effect was observed for interactions between breed and diets. In this study, the quantification of 41 fatty acids was studied. In the samples, 33 out of 41 fatty acids were identified, although only those quantified more than 0.1% are shown in the tables. Despite this, all of them have been considered for calculating SFA, MUFA, PUFA, n-3, n-6 and nutritional indices.

Breed effect on the fatty acid profile

No significant ($P<0.05$) effect of breed on total contents of SFAs, MUFAs, PUFAs, n-3, and n-6 of drumstick and breast was found. Regarding drumstick, in both breeds MUFAs were the most abundant fatty acids, with oleic acid (C18:1n9) as the predominant, followed by SFAs, with palmitic acid (C16:0) as the most abundant. In contrast, PUFA showed the lowest values, with linoleic acid (C18:2n6c) being the most common.

In the breast, SFAs were the most abundant, followed by MUFAs and PUFAs. The main fatty acids in Mos and Isa Brown were oleic acid (30.03% *vs.* 29.12%), palmitic acid (23.67% *vs*. 23.28%), and linoleic acid (18.94 *vs.* 17.46%). Concerning the nutritional indices, the breed did not have a significant effect on PUFA/SFA and n-6/n-3 ratios. Mos and Isa Brown showed similar values for PUFA/SFA in both breast and drumstick.

Diet effect on the fatty acid profile

Regarding drumstick, diet significantly ($P<0.05$) affected SFAs and n-3 contents. Our results showed that in hens fed with CF there was an increase in the contents of SFAs comparing to the values obtained in birds fed with CW. Moreover, palmitic acid was the most predominant SFA, which was significantly ($P<0.001$) greater in hens fed with control diet (CF) than the contents obtained with both alternative diets (CPT and CW).

In the breast, the diet did not affect significantly ($P>0.05$) MUFA, SFA, PUFA, n-3, and n-6 contents. However, significant effects of diet type were observed in several fatty acids. In this way, the CF diet increased significantly ($P<0.05$) linoleic acid contents (19.65 *vs*. 18.71 and 17.10 g/100 g, for CF, CPT and CW, respectively).

Discussion

Laying performance and feed consumption

The performance results (egg production) obtained for Mos breed were greater than those reported by Nguyen Van et al. (2020) in native breeds, who obtained values of 88.5 and 94.9 eggs/hen/52 weeks in Ho and Dong Tao hens respectively (at least 48.7% less than Mos fed with CF). However, it is important to highlight that Mos hens had ~27% higher feed/hen/day (g) than Ho and Dong Tao hens. On the other hand, Isa Brown performance (maximum of 83.93% in week 52) was lower than the data previously published by Świątkiewicz et al. (2018) and Świątkiewicz et al. (2020) who found the values of 90-93% (similar period) for Isa Brown hens housed in cages and fed with different diets. In addition, the aforementioned authors also found a lower daily feed intake (112–121 g/hen). Conversely, our results for performance were very similar to those (82.8%, 94.6 g of feed intake) obtained by

Ruhnke et al. (2018) at the end of the experiment. As the flock and housing parameters were the same for all hens in this study (representing local farming conditions), the different results compared to the previous researches with Isa Brown could be caused by experimental conditions such as housing system (cages/free-range) and diet formulation utilized.

Breed effect on carcass yield and commercial cuts

As expected, live and carcass weight were strongly influenced by breed (Mueller et al., 2018). Comparing Mos carcass weight (2.1 kg) to dual-purpose types (Lohmann Dual, Belgian Malines, and Schweizerhuhn fattened for 63 days), commercial broilers (Sasso 51 and Ross PM fattened for 35 and 63 days respectively), and laying hens (Lohmann Brown-Elite housed in cages at 40–48 weeks of age), our results were higher than those obtained for aforementioned hybrid lines (between 0.78 and 1.8 kg) (Mueller et al., 2018; Semwogerere et al., 2019). On the other hand, Isa Brown (1.02 kg) showed lower carcass weights than those previously published for breeds such as Lohmann Dual dual-purpose (1.45 kg) (Mueller et al., 2018), showing a very similar value when compared to Lohmann Brown-Elite spent hen (1.20 kg) (Semwogerere et al., 2019) and Belgian Malines dual-purpose (1.16 kg) (Mueller et al., 2018).

Concerning previously published results for dressing percentage, it was reported that some commercial broilers (e.g. Ross PM3 and Sasso 51) showed higher or similar values (72.9% and 69%, respectively) to those found in Mos hens. By contrast, our results for both lines (Mos and Isa Brown; 69.83% and 63% respectively) were similar to those obtained for local breeds (Italian dual-purpose Ermellinata di Rovigo and Robusta Maculata; 64.37% and 66.29% respectively) by a previous study (Rizzi et al., 2007) which found significantly higher ($P<0.01$) dressing percentages in local breeds comparing to hybrids (Hy-Line White 36 and Hy-Line Brown; 55.89% and 57.65% respectively). Laying hens are relatively small in size to reduce energy requirements since genetic improvements on the hybrid strains have focused exclusively on egg production (Limpisophon et al., 2019; Rizzi et al., 2007). In this sense, despite the lower results for live and carcass weight in industrial lines were expected, Isa Brown obtained similar values for these parameters to those obtained for some dual-purpose breeds.

Comparing our findings for noble cuts to previous studies with industrial lines, the most remarkable was the interaction between carcass yield, breast, and wing percentages since birds with higher carcass weight and dressing percentage resulted in birds with higher breast and lower wing. Despite Mos spent hen had lower values for breast than commercial broiler Ross PM3 (29.6%), showed similar parameters (experimental birds were fattened for 63 days) when compared to commercial broiler Sasso 51 (20%) and dual-purpose Lohmann Dual (19.4%), as well as higher than commercial layer type Lohmann Brown Plus (16.7%), dual-purpose Belgian Malines (16.5%), and dual-purpose Schweizerhuhn (16.5%) (Mueller et al., 2018). Whereas, just as noted for Isa Brown, breeds with lower carcass yield and similar or lower values for breast than Mos showed higher values for wing (Sasso 51: 11.7%; Lohmann Dual: 12.1%; Lohmann Brown Plus: 13.9%; Belgian Malines: 12.6%; and Schweizerhuhn: 13.0%) (Mueller et al., 2018).

Mos results for carcass yield and commercial cuts could be contemplated as satisfactory considering that besides carcass weight, the size of the breast is an important marketing criterion. Furthermore, the breast is the first cut in chicken, which results in the carcass with a well valuable characteristic (Zotte et al., 2020; Mueller et al., 2018). Concerning Isa Brown commercial cuts percentage, our results for drumstick (12.33%), thigh (16.10%), wing (11.32%), and breast (15.43%) were lower than those previously published for Lohmann Brown-Elite spent laying hens (14.2%, 36.8%, 16%, and 28.3% respectively) (Semwogerere et al., 2019). On the other hand, results for wings percentage (11.32%) were very similar to those published (~11.60%) for broilers (Ross PM3 and Sasso 51) and dual-purpose (Lohmann Dual and Belgian Malines) chicken types (Mueller et al., 2018).

A higher fat content (3.39%) found for Mos meat demonstrates that the breeding selection program of Isa Brown is focused to allocate energy for egg production and not for body tissue accumulation. This fact could be advantageous to Mos meat quality considering that leads to enhance odour, flavour and juiciness. In this way, lipids and fats in local poultry are unique and combine with odour to account for the characteristic flavour of the local breeds. For instance, local breeds from Japan (Hinai-jidori), Korea (native chickens) and India (Kadaknath) have significantly higher flavour scores compared to broilers, among other reasons, due to their fat content. Moreover, chicken meat is an important source of healthy fat (PUFAs), which contributes to avoid coronary heart diseases. On the other hand, although Isa Brown showed significant ($P<0.001$) lower results for fat (0.85%) comparing to Mos (3.39%), its meat could be an important provider of a low-fat ingredient for the food industry since there is a current demand of these products by consumers. Consequently, this meat is a natural candidate to meet this emerging demand because of its high nutrient content and relatively low caloric value (Mir et al., 2017).

Diet effect on carcass yield and commercial cuts

The differences found by the effect of the diet can be attributed to the response of a bird to its feeding since diet composition is closely related to growing changes and fat accumulation. Low fat and carbohydrate-rich diets decrease carcass yield and carcass fat (Mir et al., 2017). Thus, in the present study chicken fed with CF diet (fat-rich, low carbohydrate) had higher live and carcass weight than those fed with alternative diets (low fat; carbohydrate-rich). On the contrary, no significant ($P<0.05$) differences were observed among groups for carcass fat. This absence could be due to the genetic improvements focused on egg production, which result in the most pronounced breed effect on carcass yield characteristics.

Our results for commercial cuts were in disagreement with those found by Semwogerere et al. (2019) in Lohmann Brown-Elite spent laying hen (housed in cages at 40–48 weeks of age) supplemented with expeller press canola meal, since they found a significant effect of diet in noble parts as breast (meat and bone), thigh and drumstick. In addition, our data also disagree with Berger et al. (2021) evaluating the adaptation of slow-growing chickens (Sasso; 12 weeks of age) and broilers (Cobb 500; 5 weeks of age) to alternative diets (with local feedstuffs) in real conditions of production (on the floor and in groups). Authors showed that chickens can adapt to a diet without a significant effect on body composition and meat quality traits.

Physicochemical characteristics of meat (drumstick and breast)

Breed effect on pH, composition, and colour of meat

Different effects on pH values of poultry meat have been reported in the literature. These dissimilarities could be ascribed to several factors, e.g., breed, live weight, pre-slaughter handling, predisposition to stress, prolonged struggling, transport, access to water, diet type, and muscle glycogen reserves (Mir et al., 2017; Semwogerere et al., 2018). The pH values found in the present research were in the acceptable range of 5.61–6.10 observed in other studies with laying hens (Chueachuaychoo et al., 2011; Rizzi et al., 2007; Semwogerere et al., 2018). The results found for Mos laying hens were very similar to those obtained by Pateiro et al. (2018) in Mos young hens.

For drumstick, our findings agree with those reported by Mueller et al. (2018), who also found significant ($P<0.01$) differences among laying hen breeds. Concerning fat percentages (2.60–3.82%; Isa Brown and Mos respectively), similar results (2.67–4.00%) were obtained in a previous study (Mueller et al., 2018) comparing a commercial layer type (fattened for 63 days), dual-purpose breeds (fattened for 63 days), and commercial broilers (fattened for 35 and 63 days). Differences in the composition can be attributed to the already discussed breed effect on carcass yield and fat depot (genetic programs of hybrid lines). Concerning colour parameters, differences between breeds in drumstick samples were previously described by several authors (Jaturasitha et al., 2008; Kim et al., 2020; Mueller et al., 2018; Rizzi et al., 2007). Regarding redness, poultry meat from local breeds usually had greater a* values (darker meat) due to their intrinsic behaviour, more aggressive and active with a high stress susceptibility (Jaturasitha et al., 2008). A glycogen content reduced at slaughter, due to *ante-mortem* stress, may lead to darker meat (Chauhan and England, 2018). Nevertheless, the use of a* to measure chicken meat colour has constraints and should be done with caution, since myoglobin (which defines meat redness) is not readily detectable in chicken meat (Semwogerere et al., 2018).

Despite that, the chicken breed or muscle location generally influences the colour of meat, which is mainly associated with the pigment content, the light scattering of sarcoplasmic proteins, and absorption properties. L* of meat is closely linked to the pH value of samples (low pH, high L*) (Choe and Kim, 2020). However, in the present study, Isa Brown showed higher pH (6.06) and L* (46.13) values than Mos (5.89 and 44.15 respectively). Hence, a lower pH did not lead to an increase in L*. In this sense, we speculate that the higher L* value assessed in Isa Brown could be explained by the content and chemical state of its inherent meat pigments (e.g. heme pigments). Even so, further studies must be realized to confirm this hypothesis.

In breast, results obtained for pH were in agreement with those found by Choe and Kim (2020) in old chickens (broiler *vs*. laying hen), but in disagreement with those observed by Mueller et al. (2018) and Rizzi et al. (2007). Variations in breast pH could be due to the already discussed drumstick pH since values are influenced by similar phenomena. Considering that no significant differences were found for breast composition between Mos and Isa Brown, results were promising considering that the main components found for poultry meat in previous studies were proteins and lipids between 18.4% to 23.4%, and 1.3% to 6.0%, respectively (Mir et al., 2017). Our outcomes for chemical composition (moisture, protein, and fat) of breast were only similar to those found for moisture in the literature since we obtained higher protein and lower fat contents according to those published by Semwogerere et al. (2019) (moisture: 73.7%; protein: 22%; fat: 3.8%), Mueller et al. (2018) (moisture: 71.1–73.7%; protein: 22.4–25.1%; fat: 0.08–1.45%), and Chueachuaychoo et al. (2011) (moisture: 74.16%; protein: 22.34%; fat: 3.11%). Similar to the findings previously published by Semwogerere et al. (2019), our results indicated spent laying hen breast as a low-fat food because of its content (≤3%).

Concerning breast colour, values reported for yellowness agree with those reported by Choe and Kim (2020), who found higher ($P<0.01$) values in b* for laying hens, but differently, those authors also found higher L* ($P<0.01$) and lower a* ($P<0.01$) values. In this way, colour is closely related to meat attractiveness (Mueller et al., 2018), since it has the most influence on the purchase decisions of consumers. For instance, lower b* values obtained in Mos samples could be beneficial as this colour is preferred by some consumers because it is considered a natural feature for chickens, while high redness and low yellowness result in an undesirable pinkish colour (Semwogerere et al., 2018; Semwogerere et al., 2019).

Diet effect on pH, composition, and colour of meat

Colour variations assessed can be attributed to diets formulation since groups fed with alternative diets obtained the highest ($P<0.001$) values for a* (2.16 and 2.06 *vs*. 0.23, for CW, CPT and CF, respectively) and b* parameters (15.86 and 14.03 *vs*. 13.79, for CPT, CW and CF, respectively). Notwithstanding the presence of xanthophyll in the composition of corn, the carotenoid responsible for imparting yellow colour to chickens (Sales, 2014), groups fed with higher corn levels (CW diet) showed lower b* values than those observed for diets with lower corn levels (CPT diet). A possible explanation could be due to the higher fat contents obtained in these samples (4.50% *vs*. 2.55% and 2.77%, for CPT, CF and CW, respectively), which would lead to a more yellow appearance in the meat of hens fed with CPT (Semwogerere et al., 2019).

Regarding pH, our results were in the range (5.73–6.25) previously reported for laying hens (Mueller et al., 2018; Semwogerere et al., 2019). Our results for pH on the breast (5.92; CW group) agreed with Berger et al. (2021) who also found a higher pH value (5.89) in samples of chickens (broilers) fed with alternative diets (mixture of alternative feedstuffs). On the other hand, colour outcomes are in disagreement with those found by Semwogerere et al. (2019) who did not find any change for colour parameters in spent hens fed with different diets.

Textural parameters

Breed effect on textural parameters of breast

The results found for cooking loss (12.56% and 12.32% for Mos and Isa Brown respectively) were higher than those previously reported by Mueller et al. (2018) in spent-hen Lohmann Brown Plus (9.4%) as well dual-purpose breeds such as Lohmann Dual (11.3%), Belgian Malines (10.90%), Schweizerhuhn (8.3%). On the other hand, values were similar to those observed in commercial broiler Sasso 51 (12.2%)

and lower than commercial broiler Ross PM3 (16.1%) (Mueller et al., 2018). Regarding shear force, the values obtained were in agreement with those shown by Rizzi et al. (2007), who also observed similar values between breeds (local *vs*. hybrids).

The spent hen meat has been underutilized for human consumption mainly due to its undesirable tough texture caused by the extended slaughter age and breed effect, which could lead to an increase in muscle fibre diameter, more stroma protein content, and heat-stable cross-linked connective tissues. Therefore, the meat of these animals requires more cooking time, which could affect its quality (Chueachuaychoo et al., 2011; Limpisophon et al., 2019; Mir et al., 2017; Semwogerere et al., 2018). In this way, the values obtained were higher than those found in previous studies with Mos young hens (14.83N) (Pateiro et al., 2018), local breeds (14.12 N) (Cassandro et al., 2015), and broilers (7.64N) (Wattanachant et al., 2004). The same happened with the values obtained for the TPA test. Our results were satisfactory compared with those reported in the literature for laying hens, since they were lower than those previously reported (Chueachuaychoo et al., 2011; Khwunsiri et al., 2007; Limpisophon et al., 2019).

Similar to the already discussed colour parameters (i.e., desirable higher b*/lower a* in meat), tenderness is also a determinant in the purchase intent of consumers (Semwogerere et al., 2019). With all results in mind, it is easy to suggest that the differences in the values obtained for texture with those observed in other spent hens, young hens and broilers could be related to the age and the breed of chickens.

Diet effect on textural parameters of breast

Results for shear force were in disagreement with those observed by Semwogerere et al. (2019) who reported that spent laying hens fed with conventional diets had lower (P<0.001) values comparing to alternative diets (12.37 *vs*. 15.43 N, for conventional *vs*. alternative diets, respectively). On the other hand, regarding TPA-test, our results agree with Mir et al. (2017) who published that the texture and degree of firmness of the meat is a function of the amount of water held intramuscularly. Therefore, water tightly bound to the muscular proteins has a swelling effect on muscle proteins, occupying the spaces between myofibrils and giving the meat a firmer structure. In the present study, CF group samples showed higher textural parameters for hardness which could be attributed to the lower cooking loss percentage (higher water holding capacity) of the meat assessed. However, the tough texture assessed for the CF group (diet effect) could also be attributed to other parameters not assessed in the present study (e.g. muscle fibre size and arrangement; connective tissue amount, spatial distribution, and composition; and *post-mortem* biochemical events) (Limpisophon et al., 2019). Hence, further investigations should be realized to evaluate the diet effect on the abovementioned parameters to corroborate our results.

In addition, results were similar to those found by Pateiro et al. (2018), who found significant differences among different diets (fodder, corn and linseed). Conversely, our outcomes disagree with those reported by Franco et al. (2012 b), who did not find a significant effect of finishing diet on textural parameters of Mos roosters.

Fatty acid profile (drumstick and breast)

Breed effect on the fatty acid profile

Results for total contents of SFAs, MUFAs, PUFAs, n-3, and n-6 of drumstick and breast disagreed with those observed in previous studies conducted with local chickens (Wattanachant et al., 2004) and spent hens (Chueachuaychoo et al., 2011). In these studies, the meat of birds showed higher percentages of MUFAs and PUFAs and lower contents of SFAs in comparison to industrial lines. Our findings for the main fatty acids match with those obtained by Kim et al. (2020) who also reported these three fatty acids as the most abundant, being oleic acid which showed the highest values (between 33.85% and 38.04%). The results were also supported by those of Chueachuaychoo et al. (2011) who found a similar fatty acid composition in the breast of spent hens. Nevertheless, these authors found slightly higher values for oleic acid (31.40%) and palmitic acid (24.60%). On the contrary, our SFAs outcomes were higher than those published by Husak et al. (2008) in broilers, but lower for MUFAs and PUFAs (SFAs: 32.31%; MUFAs: 39.13%; PUFAs: 28.57%).

The nutritional indices allow evaluating the ratio between healthy and unhealthy fatty acids, giving information about the healthy fat composition in the diet (Gálvez et al., 2020). The nutritional indices values obtained in the present study are close to nutritional recommendations for the human diet (0.85) (FAO, 2010). On the other hand, although the values obtained for n-6/n-3 ratio were higher than those recommended (n-6/n-3<4) (FAO, 2010), breast showed better results (11.50 *vs*. 19.71 for breast and drumstick, respectively), being Isa Brown which obtained the lowest values.

Finally, our results can be considered satisfactory since hens showed a more favourable fatty acid profile (higher PUFA, similar MUFA, and lower SFA) than previous findings for Mos breed (Pateiro et al., 2018) and spent hens (Semwogerere et al., 2019). The fatty acid profile reported by Pateiro et al. (2018) in Mos young hens (20 weeks of age) showed MUFAs (37.70%–40.13% for drumstick and breast, respectively) as predominant fatty acids, followed by SFAs (35.57%–35.63% for drumstick and breast, respectively) and PUFAs (25.62%–22.74% for drumstick and breast, respectively). On the other hand, concerning spent hens of the hybrid lines (Lohmann Brown-Elite at 40–48 weeks of age), Semwogerere et al. (2019) reported 38%, 33%, and 29% for SFA, MUFA and PUFA respectively.

Diet effect on the fatty acid profile

The differences in fatty acid profile among groups could be attributed to the lipid amount (almost two times higher in CF) and fatty acid profile of the different bird diet since this is an essential fatty acid that cannot be synthesized by birds (Díaz et al., 2013). In chickens, it is well known that lipids deposited as carcass fat are likely due to dietary fatty acid intake (Franco et al., 2020; Mir et al., 2017; Semwogerere et al., 2019). As we mentioned above, the differences observed in the fatty acid profile of drumstick and breast are in accordance with diet formulation since hens feed had differences in fat content (5.01%, 2.07% and 2.89%, for CF, CPT and CW, respectively). Finally, as with the breed effect, diet did not have a significant effect on nutritional ratios. In this case, alternative diets did not allow improving the ratios PUFA/

SFA and n-6/n-3. Although, the CPT diet is beneficial due to being more favourable in terms of nutritional indices (lower SFA and n6/n3 ratio and higher PUFA).

As a general conclusion, data obtained for meat quality and laying performance showed that the Mos breed would be a good alternative to the dual-purpose (egg and meat) since it is a rustic breed and it is well adapted to different diets. In addition, our results indicated that the Mos breed showed similar egg production to Isa Brown if fed with alternative diets. The results found in Mos for carcass weight, dressing and breast percentage, as well as found for Mos and Isa Brown for meat composition (high protein and low fat content of the breast), indicate these animals as a potential source for the development of high-quality meat-based products in line with current consumer demands in terms of healthy meat. Finding an economic purpose for spent hens, meat could contribute to reduce the cost of removing spent laying hens from the farms that often exceeds their value for meat (economic burden). In future studies, it is suggested to investigate the development of meat-based food formulations from this type of meat, as well as the assessment of chemical composition, sensorial analysis, shelf-life, and viability of these products.

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